IMAGINARY FIELDS

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Nonlinear dynamical modeling of interaction between automatic and conscious processes in the human brain is considered in terms of the quaternion fields. The interaction is due, particularly, to the nonlinear firing rate of neurons. Possible connection of consciousness with the general field theory is indicated. A new type of symmetry between dynamics of real and imaginary fields is pointed out.

From the physical-mathematical point of view consciousness (C) is a mystery. It is desired to catch C into some sort of equations. The common knowledge is that C is somehow connected with the electrochemical activity in the brain. So, it seems logical to start with equations for these processes. The brain activity revealed the regime of scale-similarity [1-3], which is typical for systems with strong interaction of many degrees of freedom (particularly, for turbulence [4]). Corresponding equations can be formally written and are rather complicated. However, at this stage of our understanding of C, the precise form of equations is not critical. One can use various simplified models. The important question is how to connect these equations with C? The C-processes are subjective and, as far as we know, they can not be measured directly by the objective methods, which are used for measuring the electrochemical (automatic) processes. At the same time, there are reasons to believe that C-processes can interact with automatic (A) processes. We need equations for A-fields and C-fields, which interact despite the fact that C-field have a different nature and can not be measured directly by the same methods as A-fields.

In recent papers [5-8] an approach to nonlinear dynamical modeling of interaction between these two processes was presented. The idea is to use the quaternion field with real and imaginary components representing A- and C-processes. The subjective C - experiences were divided into three major groups: sensations (S), emotions (E) and reflections (R). Note, that subjective S should be distinguished from the automatic sensory input into the neuron system of the brain [9]. The $A - C$ interaction is due to the nonlinearity of the system. This approach was illustrated on the nonlinear equation for the current density in the cortex.. The nonlinearity is determined by the sigmoidal firing rate of neurons. Perspective for the laboratory testing of this approach were also indicated as well as some more general approaches [5-8].

To be specific, consider quaternion:

$$q = \alpha + i_p \psi_p \tag{1}$$

Here $\alpha(t)$ is the average (spatially uniform) current density perpendicular to the cortical surface, $\psi_p(t)$ represent the indicated above (S, E, R) - effects and

summation is assumed on repeated subscripts from 1 to 3. The imaginary units i_p satisfy condition:

$$i_p i_s = \varepsilon_{psr} i_r - \delta_{ps} \tag{2}$$

where ε_{psr} is the unit antisymmetric tensor and δ_{ps} is the unit tensor. Formula (2) is a compact form of conditions: $i_1^2 = i_2^2 = i_3^2 = -1$, $i_1 i_2 = -i_2 i_1 = i_3$, $i_2 i_3 = -i_3 i_2 = i_1$, $i_3 i_1 = -i_1 i_3 = i_2$.

The model equation for the quaternion q has the form [5-8]:

$$\frac{\partial q}{\partial t} + kq = f(q + \sigma) + \phi, \quad \sigma = s + i_p \varphi_p \tag{3}$$

Here k is the relaxation coefficient, f represents the sigmoidal firing rate of neurons [for example, $f(\alpha) = \tanh(\alpha)$], ϕ represents the external electromagnetic (EM) excitations. The quaternion σ is the averaged sensory input, which has real component s and imaginary components φ_p (for so-called extra-sensory effects, if they exist).

For the case of spatially nonuniform $q(t, \mathbf{x})$, $\sigma(t, \mathbf{x})$ and $\phi(t, \mathbf{x})$ we can use more general equation, which include typical propagation velocity of signals in the neuron system of the cortex v. Time differentiation of (3), simple algebra and addition a term with the two-dimensional spatial Laplacian Δ gives [5-8]:

$$\frac{\partial^2 q}{\partial t^2} + (k + m)\frac{\partial q}{\partial t} + (km - v^2 \Delta) q = (m + \frac{\partial}{\partial t}) f(q + \sigma) + \frac{\partial \phi}{\partial t} \tag{4}$$

where m is an arbitrary parameter (see below). Real and imaginary projections of (4) give a system of four partial differential equations for α and ψ_p. If we put $\psi_p = 0$ and $\phi = 0$, than equation for α will be similar in spirit to equation used for interpretation of EEG an MEG spatial patterns (see recent paper [10] and references therein). In this context we have parameters: $k \sim m \sim v/l$, where l is the connectivity scale.

Returning, for simplicity, to (3) and using $f(\alpha) = \tanh(\alpha)$, we have explicit projections [7]:

$$\frac{\partial \alpha}{\partial t} + k\alpha = \frac{\sinh[2(\alpha + s)]}{\cosh[2(\alpha + s)] + \cos(2\theta)} + \phi, \quad \theta^2 = \theta_p^2, \quad \theta_p = \psi_p + \varphi_p \tag{5}$$

$$\frac{\partial \psi_p}{\partial t} + k\psi_p = \frac{\theta_p \theta^{-1} \sin(2\theta)}{\cosh[2(\alpha + s)] + \cos(2\theta)}, \quad p = 1, 2, 3 \tag{6}$$

Some general conclusions can be made without solving these equations. Firstly, if $\psi_p(0) = 0$ and $\varphi_p(t) \equiv 0$ (no extra-sensory effects), than $\psi_p(t) \equiv 0$. In other words, consciousness, according to these equations, can not appear from nothing. Secondly, presence of $\psi_p \neq 0$ through field θ (if not nullified by φ_p) changes the measurable field α, so the model is testable. Thirdly, if the neuron system (NS) is not working ($f(\alpha) \equiv 0$), then $\psi_p(t)$ will decay exponentially ($k > 0$). Finally, if $\psi_p(0) \neq 0$ and NS is working, than evolution $\psi_p(t)$ depends

on $\alpha(0)$ and is influenced externally by the sensory input and by EM excitations. The nonlinearity of the system suggests that the efficiency of external influence depends not only on amplitude (of, say, $s(t)$), but also of the shape (spectral content).

Generally, $\psi_p(t, \mathbf{x})$ signifies the presence of imaginary components of EM field in the brain. Let us assume, as an adventure, that such field can exist (at least, for a short time) in empty space (perhaps in a brane [11], which encloses our ordinary 4D spacetime). Than, it seems natural, that such field can propagate. According to the described model, real and imaginary components of EM field interact in the presence of healthy NS. This interaction, apparently, is symbiotic and stable. However, in special circumstances, when NS is strongly disturbed, we can expect shedding of a part of imaginary EM field from this NS, propagating and attracting to another NS (φ_p - effect in the model). In this way we can interpret observed instances of telepathy, reincarnation ("past life memory" connected with fatal accidents) and related effects, which can not be explained by traditional approaches. New type of protocols have to be developed for laboratory testing of the C-modeling [5].

Interaction between NS's by means of the field $\varphi_p(t, \mathbf{x})$ requires more general modeling. It will be very interesting to incorporate fields $\psi_p(t, \mathbf{x})$ and $\varphi_p(t, \mathbf{x})$ into the framework of contemporary field theory. Possible candidates are so-called "ghosts" [11,12] with negative norm (energy). The negative norm corresponds to imaginary field (IF). The string theorists are trying to get rid of ghosts (with exception of Faddeev-Popov variety). But cleansing procedures look rather artificial - for open bosonic string it requires to rise spacetime dimension to $D = 26$. Perhaps we should embrace IF, but in different context. Could it be that brain tissue with healthy NS attracts IF and such attraction is used by Nature to create conscious beings? That is a thrilling (trillion dollars) question.

It is not that we need the full-blown strings theory to deal with consciousness. But, it is important to know that (ψ, φ) - fields, which we introduced phenomenologically, can be derived from the first principles [13]. On another hand, recognition of IF as legitimate fields can help in development of the general field theory. Note, that fields, which can be responsible for the accelerated expansion of the Universe [12] (particularly, distributed sources [14]), potentially may also produce C-effects. This is a little scary project. It leads, for example, to a new type of symmetry - between real fields (RF) and IF. From the "point of view" of IF-world our RF are imaginary [15]. We will not discuss here philosophical aspects of such symmetry.

From practical (medical, technological) point of view, the most important is to know - what is so special about the brain tissue with healthy NS, which attracts IF and give them a life, so to speak? And related question - can we artificially create a composite material, which will attract and support IF? The described above simple model can be a hint, a beginning of a long journey in answering these questions. Numerical experiments with this model are in progress and results will be compared with observations and reported elsewhere.

References

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[15] For example, multiplication of equation (3) by imaginary unit i_p gives equation for a quaternion with real component $-\psi_p$ and corresponding imaginary component α.